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# Soil quality and hardwood forest regeneration in the Big Darby Creek headwaters of Logan County, Ohio.

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December 2014

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## **Introduction**

Having approached The Nature Conservancy in Ohio with an interest in volunteering to augment my academic studies I was directed to complete a small field study of soil properties that might affect the regeneration of hardwood trees in agricultural old fields at a nature preserve in Logan County, Ohio. The aim was to determine, via sampling soil properties along 3 paired forest-old field transects, if there were any detectable differences that might explain the apparently slow regeneration of hardwood forest tree species in the old fields. Hardwood forest is the intended and desired land cover for the preserve and is believed to be the best land cover for the headwaters of Big Darby Creek in this particular area and on the preserve.

## **Geological History**

Geology offers scientists the opportunity to look into earth's past. With this ability, scientists can determine what process took place during certain time periods, and ultimately, how it shaped the landforms and structures we naturally have today. For a soil scientist, this is an important aspect to understand. By researching the geological past of a park, cropland, or field, the soil scientist can formulate an idea of what physical and chemical characteristics the soil might have without having to dig. By cross referencing glacial and bedrock geological maps courtesy of the U.S. Geological Survey's *Geologic Map of the United States*, certain landforms match up with geologic times. By concentrating on Logan County, where The Nature Conservancy's 801-hundred acre park of The Big Darby Headwaters Nature Preserve exists, the geological maps allowed further understanding of the land's geology, history, and predictability.

## **Bedrock Geological Map of Ohio**

The Ohio Division of Geological Survey compiled the Bedrock Geologic Map of Ohio data since 1920. Looking over the map, Ohio is underlain by sedimentary rocks older than 250 million years. These rocks consist mostly of limestone, shale, carbonate, siliciclastic (accumulation of silicate clasts), evaporate (deposits of soluble salts typically gypsum and halite rock salt), and organoclastic strata of sedimentary origin that range in age from Upper Ordovician to Upper Carboniferous-Lower Permian due to shallow seas.

The Upper Ordovician was a time of calcite sea geochemistry in which low-magnesium calcite was the primary inorganic marine precipitate of calcium carbonate. Carbonate hardgrounds were thus very common, along with calcitic ooids, calcitic cements, and invertebrate faunas with dominantly calcitic skeletons. Over time, massive glaciers formed, causing shallow seas to drain and sea levels to drop. The Upper Carboniferous-Lower Permian System is divided into two Subsystems, the Mississippian and Pennsylvanian. Mississippian strata are mostly shales and sandstones that occur locally in various proportions. Pennsylvanian strata consist mainly of a diverse array of alternating sandstones, siltstones, shales, mudstones, limestones, and underclays. This is seen in the below paragraph of the color legend and explanation of the Silurian, Ordovician, and Devonian Systems.

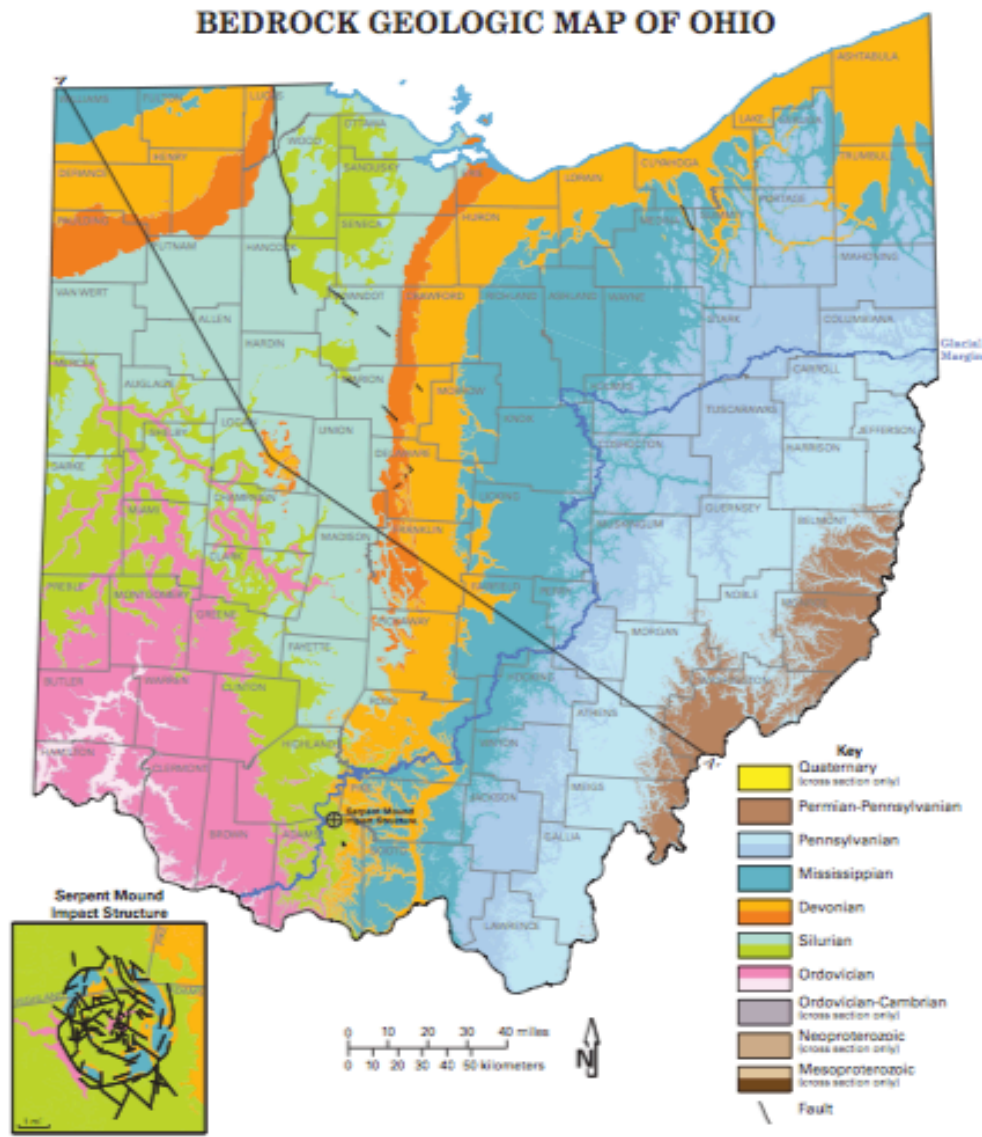


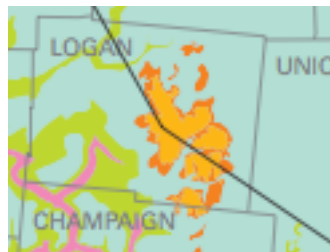
Figure 1. Created by Andrew Alden from the U.S. Geological Survey's *Geologic Map of the United States*, 1974, the Bedrock Geologic Map of Ohio shows the different layers of geological time periods that are significant in the bedrock of Ohio.

The Upper Ordovician and Upper Carboniferous-Lower Permian System both explain historically why Ohio is dominated with so much limestone, shale, and carbonates. By taking this into consideration, it explains the formation of the topography in the study area. With these chemical and physical properties in the area, we can predict what the soil characteristics would be like before taking samples. The limestone and carbonates provides a balance for acidic pH

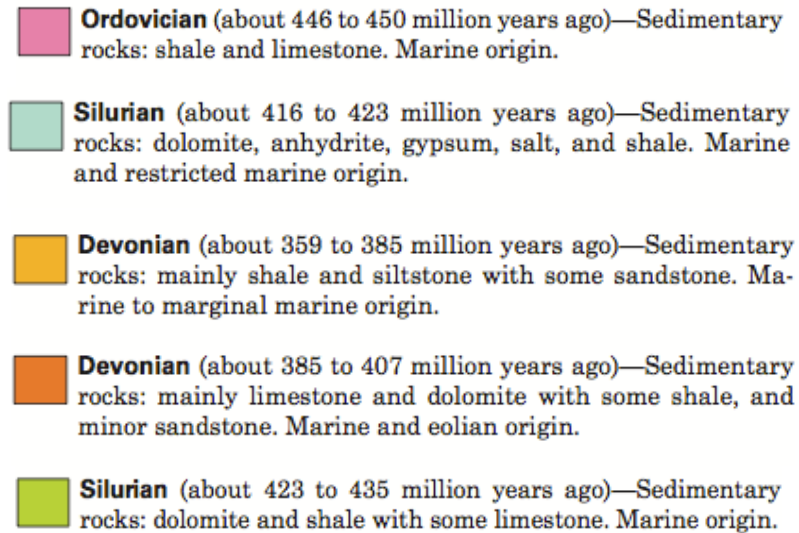
values. The clay minerals in some shale-derived soils have the ability to absorb and release large amounts of water, which is useful for plant growth.

### **Bedrock Geological Map of Ohio, Logan County**

Fig. 2 the expanded in map of Ohio shows that at the surface of Logan County an irregular veneer of mainly unconsolidated Quaternary sediments conceal most bedrock units occurring northward and westward of the glacial margin. Quaternary sediments refer to sediments left during the Quaternary period, which was defined by the cyclic growth and decay of massive continental ice sheets. Strata of the Ordovician System are the oldest exposed rocks in Ohio and consist mainly of alternating shale and limestone sequences. Logan County is seen with this Strata system as seen in fig.2. Shale is a dominant product in the Ordovician System. Shale is a fine-grained clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and silt-sized particles of mainly quartz and calcite.



*Figure 2. Expanded Map of Logan County in Ohio, taken from the U.S. Geological Survey's Geologic Map of the United States, 1974.*



*Figure 3. Color Legend taken from the U.S. Geological Survey's Geologic Map of the United States, 1974.*

Looking at Fig 2. Logan is a part of the Silurian System, in which strata are mostly dolomites with lesser amounts of shale. Dolomite is an anhydrous (no water) carbonate mineral composed of calcium magnesium carbonate. Dolomite is also used to describe the sedimentary carbonate rock, which is composed predominantly of the mineral dolomite. Normal limestone is primarily made up of calcite and aragonite, but dolomite forms in the stone when the calcium ions in the calcite part are replaced by magnesium ions. This is important to understand because the dolomite is a carbonate rock like shale and limestone, which aids in neutralizing acidic soil. With the dolomite, shale and limestone, the soil pH can be regulated for flora and fauna growth.

### **Glacial Map of Ohio**

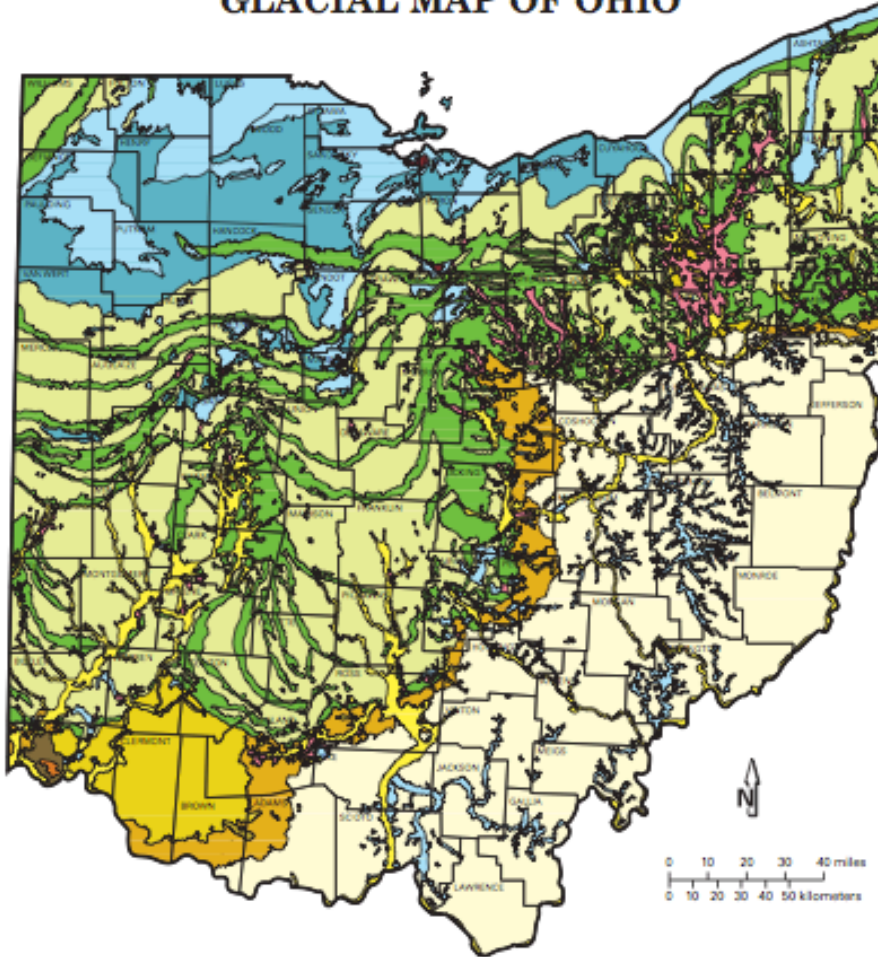
Ohio was covered by the last two glaciations, known as the Wisconsinan and the Illinoian. The most recent glacier in the past million years was the Wisconsinan. This glaciation



ended 14,000 years ago. Glaciated regions tend to have abundant resources of sand and gravel. Within these glaciations, Ohio had three-quarters of its surface covered by sheets of ice 1 mile thick. Although the Illinoian ice sheet covered the largest area of Ohio, its deposits are at the surface only in a narrow band from northeast Cincinnati to the Ohio-Pennsylvania border.

The material left by the ice sheets consists of mixtures of clay, sand, gravel, and boulders in various types of deposits of different modes of origin. Rock debris carried along by the glacier was deposited in two principal fashions; either directly by the ice or by melt water from the glacier. Material that reached the ice front was carried away by streams of melt water, which formed outwash deposits. Material deposited by water on and under the surface of the glacier itself formed features called kames and eskers, which are recognized by characteristic shapes and composition. A distinctive characteristic of glacial sediments that have been deposited by water is that the water sorted the material. Thus, outwash, kame, and esker deposits normally consist of sand and gravel. The large boulder-size particles were left behind and the smaller clay-size particles were carried far away, leaving the intermediate gravel and sand-size material along the stream courses. Material deposited directly from the ice was not sorted and ranges from clay to boulders. Some of the debris was deposited as ridges parallel to the edge of the glacier, forming terminal or end moraines, which mark the position of the ice when it paused for a period of time possibly a few hundred years. When the entire ice sheet receded because of melting much of the ground-up rock material still held in the ice was deposited on the surface as ground moraine.

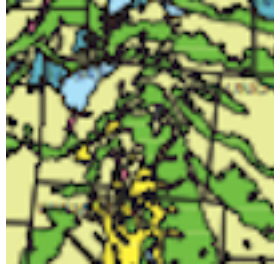
## GLACIAL MAP OF OHIO



*Figure 4.* U.S. Geological Survey's *Geologic Map of the United States*, Glacial Map of Ohio displays the different layers of parent materials and soil forming factors due to the Wisconsin, Illinoian and Pre-Illinoian eras.

The southeast corner of Logan County where the park is located is mainly comprised of ground moraine and ridge moraine from the Wisconsin glacial period as seen in Fig. 5. These two moraines are streaked across the landscape of Logan County due to the receding of the glacier. A ground moraine consists of an irregular blanket of till deposited under a glacier. Composed mainly of clay and sand, it is the most widespread deposit of continental glaciers. Although seldom more than 5 meters thick, it may attain a thickness of 20 meters. A lateral moraine consists of debris derived by erosion and avalanche from the valley wall onto the edge of a glacier and ultimately deposited as an elongate ridge when the glacier recedes. A medial moraine

consists of a long, narrow line or zone of debris formed when lateral moraines join at the intersection of two ice streams; the resultant moraine is in the middle of the combined glacier. It is deposited as a ridge, roughly parallel to the direction of ice movement.



*Figure 5.* Expanded map of the U.S. Geological Survey's *Geologic Map of the United States*, Glacial Map of Ohio, located in Logan County.

The different formations of ground moraine, lateral moraine and medial moraine help to explain the formation of the topography of the surrounding area. The area of Logan County where the study area is located differs in altitude and contains many hills, while the geography of some nearby areas are very flat with little to no slope. The difference in this geography between the study area's location and the surrounding areas correlates with the Bedrock Map and Geologic Map.

### Existing Soil Information



Figure 6. Web Soil Survey for the study area provided by NRCS.

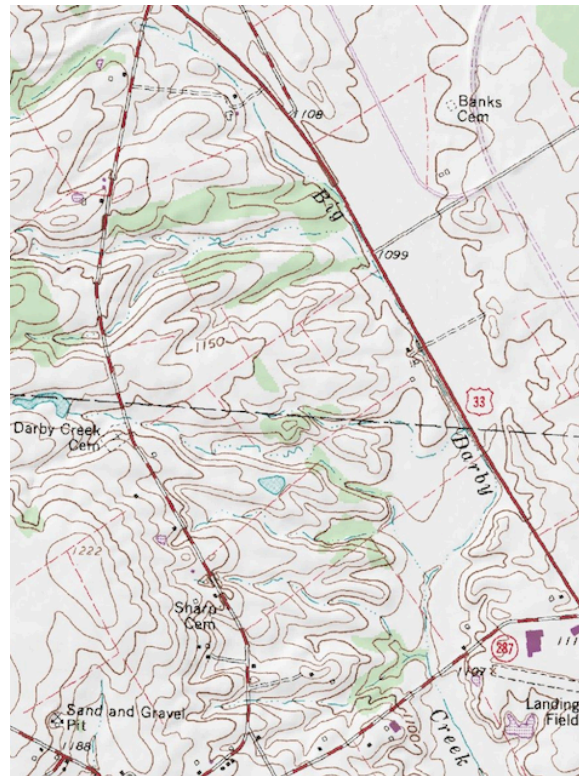
## Map Unit Legend

Logan County, Ohio (OH091)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ag	Algiers silt loam	19.6	3.6%
FuA	Fulton silt loam, 0 to 4 percent slopes	0.2	0.0%
La	Latty silty clay	25.9	4.8%
NaA	Nappanee silt loam, 0 to 2 percent slopes	35.4	6.6%
NaB	Nappanee silt loam, 2 to 6 percent slopes	182.8	33.9%
Pd	Paulding clay	10.0	1.8%
ScC2	St. Clair silt loam, 6 to 12 percent slopes, moderately eroded	131.3	24.3%
ScD2	St. Clair silt loam, 12 to 18 percent slopes, moderately eroded	101.6	18.8%
ScE2	St. Clair silt loam, 18 to 35 percent slopes, moderately eroded	4.3	0.8%
Sh	Shoals silt loam	28.9	5.4%
<b>Totals for Area of Interest</b>		<b>540.1</b>	<b>100.0%</b>

Figure 7. Map Unit Legend of the Web Soil Survey for the study area provided by NRCS.

The area of interest (AOI) map produced by NRCS Soil Survey, shows that the land is relatively newly formed from two different glacial plates. As discussed in the previous section, the AOI and the topographical map of the area, (Fig. 11) shows strong evidence that the glacial belt retreated from there due to the tightly folded sedimentation. This is due to the fact that the AOI exhibits the melting barrier with end and ground moraine. The ground moraine and end moraine deposited lots of Calcium, and CaCO<sub>3</sub> (lime) and Shale (quartz and calcite).

The majority of the AOI is silt loam in areas NaB (Nappanee silt loam, 33.9% AOI), ScC2 (St. Clair silt loam, 24.3% AOI) and ScD2 (St. Clair silt loam, 18.8% AOI).



*Figure 8.* Topographical Map of the study area provided by MyTopo. This figure shows the layout of the different elevations in the Nature Preserve.

One of the least concerning factors in planting hardwood forests is soil moisture. As long as the conditions are not in arid environments, hardwood species can germinate in a variation of seedbeds (Sutherland, Hale, and Hix, 8). Table 7 shows that the soil data collected for soil moisture was found to be statistically significant using the Duncan Grouping, between transects taken from wooded areas vs. open field areas. The mean in A is more significant since it is a larger number; therefore, it has more soil moisture than the wooded areas.

Erosion does not seem to have detrimental future effects. Slopes range from 0-35 percent slopes across the entire AOI. However, the soil erosion map provided by the NRCS Web Soil Survey showed no immediate danger of erosion, and should not affect the seedlings, especially since there is already a great succession of prairie weeds and grasses to hold the soil.

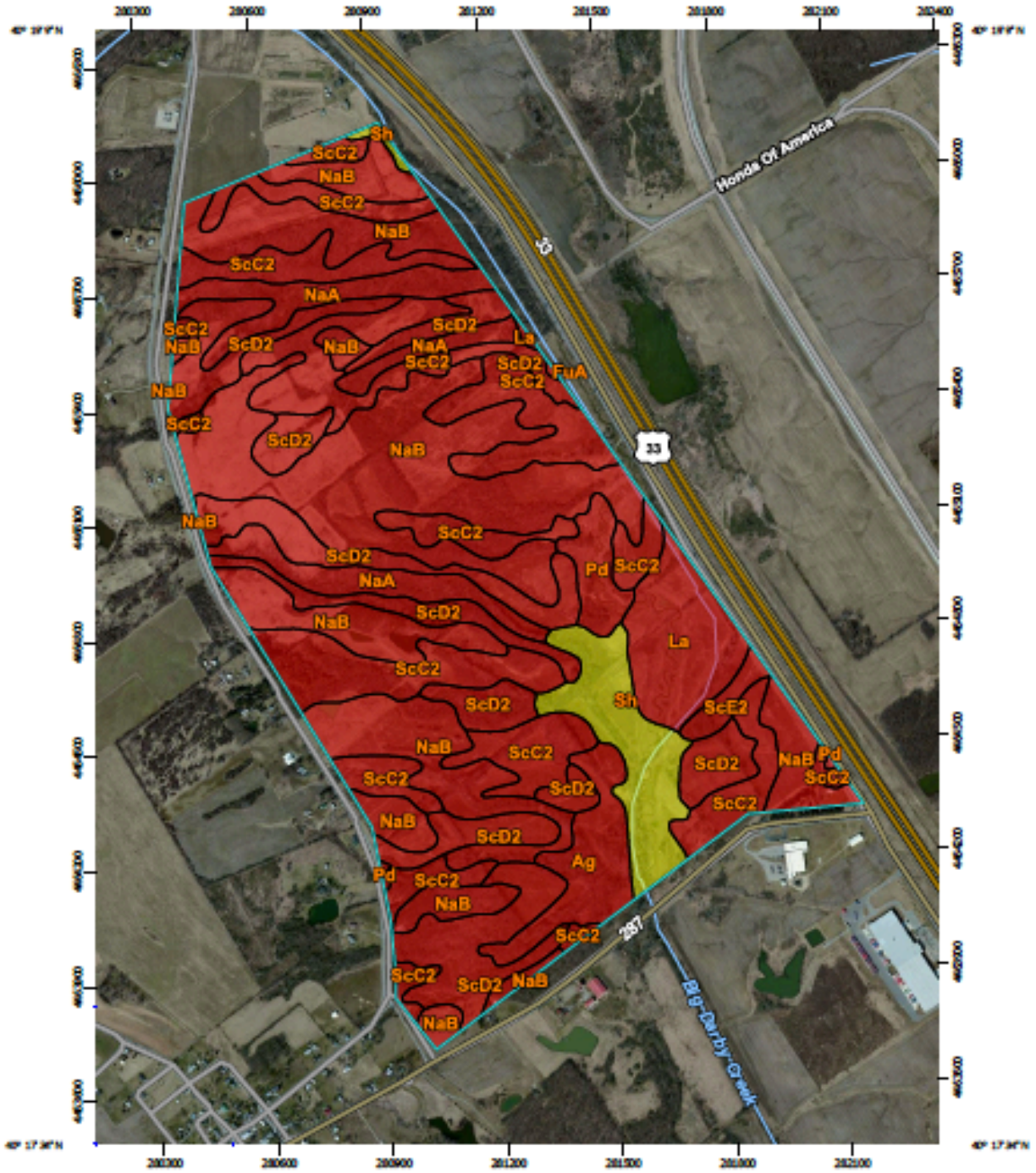


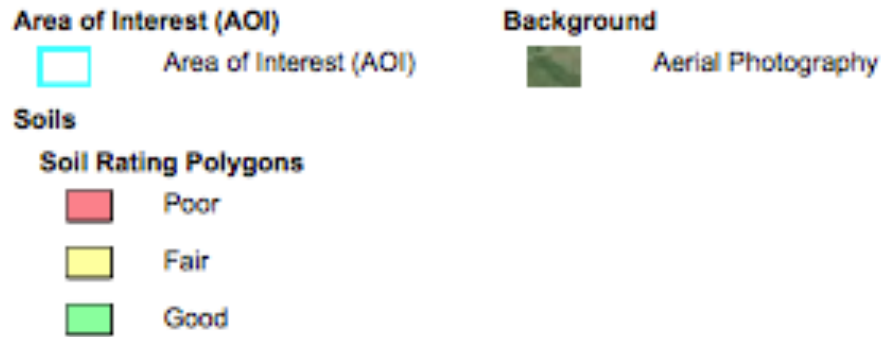
Figure 9. Topsoil Source Map from the Web Soil Survey for the study area provided by NRCS. The majority of the AOI is shown to be poor topsoil indicated in the red shading.

**Tables—Topsoil Source (Topsoil Source)**

Topsoil Source— Summary by Map Unit — Logan County, Ohio (OH091)						
Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres In AOI	Percent of AOI
Ag	Aiglers silt loam	Poor	Aiglers (90%)	Wetness (0.00)	19.6	3.6%
FuA	Fulton silt loam, 0 to 4 percent slopes	Poor	Fulton (95%)	Wetness (0.00) Too clayey (0.00)	0.2	0.0%
La	Latty silty clay	Poor	Latty (90%)	Too clayey (0.00) Wetness (0.00)	25.9	4.8%
NaA	Nappanee silt loam, 0 to 2 percent slopes	Poor	Nappanee (95%)	Too clayey (0.00) Wetness (0.14) Exchange capacity (0.97)	35.4	6.6%
NaB	Nappanee silt loam, 2 to 6 percent slopes	Poor	Nappanee (95%)	Too clayey (0.00) Wetness (0.14) Exchange capacity (0.97)	182.8	33.9%
Pd	Paulding clay	Poor	Paulding (95%)	Too clayey (0.00) Wetness (0.00)	10.0	1.8%
ScC2	St. Clair silt loam, 6 to 12 percent slopes, moderately eroded	Poor	St. Clair (95%)	Too clayey (0.00) Wetness (0.89) Slope (0.96) Carbonate content (0.99) Exchange capacity (0.99)	131.3	24.3%
ScD2	St. Clair silt loam, 12 to 18 percent slopes, moderately eroded	Poor	St. Clair (100%)	Slope (0.00) Too clayey (0.00) Wetness (0.89) Carbonate content (0.99) Exchange capacity (0.99)	101.6	18.8%
ScE2	St. Clair silt loam, 18 to 35 percent slopes, moderately eroded	Poor	St. Clair (100%)	Slope (0.00) Too clayey (0.00) Wetness (0.89) Carbonate content (0.99) Exchange capacity (0.99)	4.3	0.8%
Sh	Shoals silt loam	Fair	Shoals (90%)	Wetness (0.53)	28.9	5.4%
<b>Totals for Area of Interest</b>					<b>540.1</b>	<b>100.0%</b>

Table 1. Topsoil Source Chart from the Web Soil Survey for the study area provided by the NRCS.





*Figure 10.* Topsoil Source Map Legend from the Web Soil Survey for the study area provided by the NRCS.

Viewing the Topsoil Map from the Web Soil Survey provided by the NRCS, all but one soil unit in the AOI is colored red. This red, from Fig. 9 indicates very poor levels of topsoil. The only topsoil unit that is fairly covered in topsoil, indicated by the yellow coloring, is unit symbol Sh the Shoals silt loam. This unit is only 28.9 acres, worth 5.4% of the entire AOI.

In the Web Soil Survey Report, Pd (Paulding clay) has highest organic matter rating (percent), of 3.03. While NaB covers most of the AOI at 33.9%, the organic matter is 1.36 rating percent. ScC2 and ScD2 together create a large area of the AOI at 43.1%, they both have relatively low organic matter at 1.04 rating percent. However, with the field now covered in prairie weeds and grasses, the organic matter should be enough to help support the biodiversity and fertility in the soil, thus adding organic matter is not a concern.

### **Research- Hypothesis**

Qualitative field observations suggest that the study area's land use history may have substantially altered soil properties such as topsoil thickness (due to erosion and translocation) and that these alterations may affect the regeneration of native hardwood forest.

## **Equipment Used**

The Hanna Instruments HI98331 Soil Test Direct Soil EC Tester was used to determine the electrical conductivity and soil temperature. The conductivity range can be calibrated at one point and is designed to be performed in a standardized solution. Range: conductivity: 0.00 to 4.00 mS/cm (dS/m), Temperature Range : 0.0 to 50.0 degree C. Resolution: Conductivity: 0.01 mS/cm, Temperature: 0.1 degree C. Accuracy: Conductivity: +/-0.05 mS/cm (0.00 to 2.00 mS/cm), +/-0.30 mS/cm (2.00 to 4.00 mS/cm), Temperature: +/-1 degree C. Temperature Compensation: Automatic, Temperature coefficient (beta) fixed at the rate of 2 percent degree C.

A tool known as the dual pH and fertilizer tester dual pronged probe was used to measure N-P-K and pH. This tool accurately determines acid/alkaline soil composition, and monitors a combination of nitrogen, phosphorus and potash to show whether fertilizer levels are too high or too low in the tested soil.

The Extech MO750 Soil Moisture Meter was used to measure the moisture levels in the soil, and monitors moisture levels in soil from 0 to 50 percent.

## **Transect Mapping**

The determining factor for mapping out the six soil transect locations, was cross referencing the surface and geologic maps. Using the topography map (Fig. 11) as a guideline, the six soil transects allowed for the three soil plots in each transect to have a slope. It was important to include the slope in each plot of the transects in order for a better gradient to measure movement of soil minerals and properties. The map below (Fig. 10) shows sampling

locations. Rectangles with the orange/yellow perimeter are the soil transects for open field areas. Rectangles with the pink/red perimeter are the soil transects for wooded areas. All six of these transects follow a sloping gradient along the headwaters.

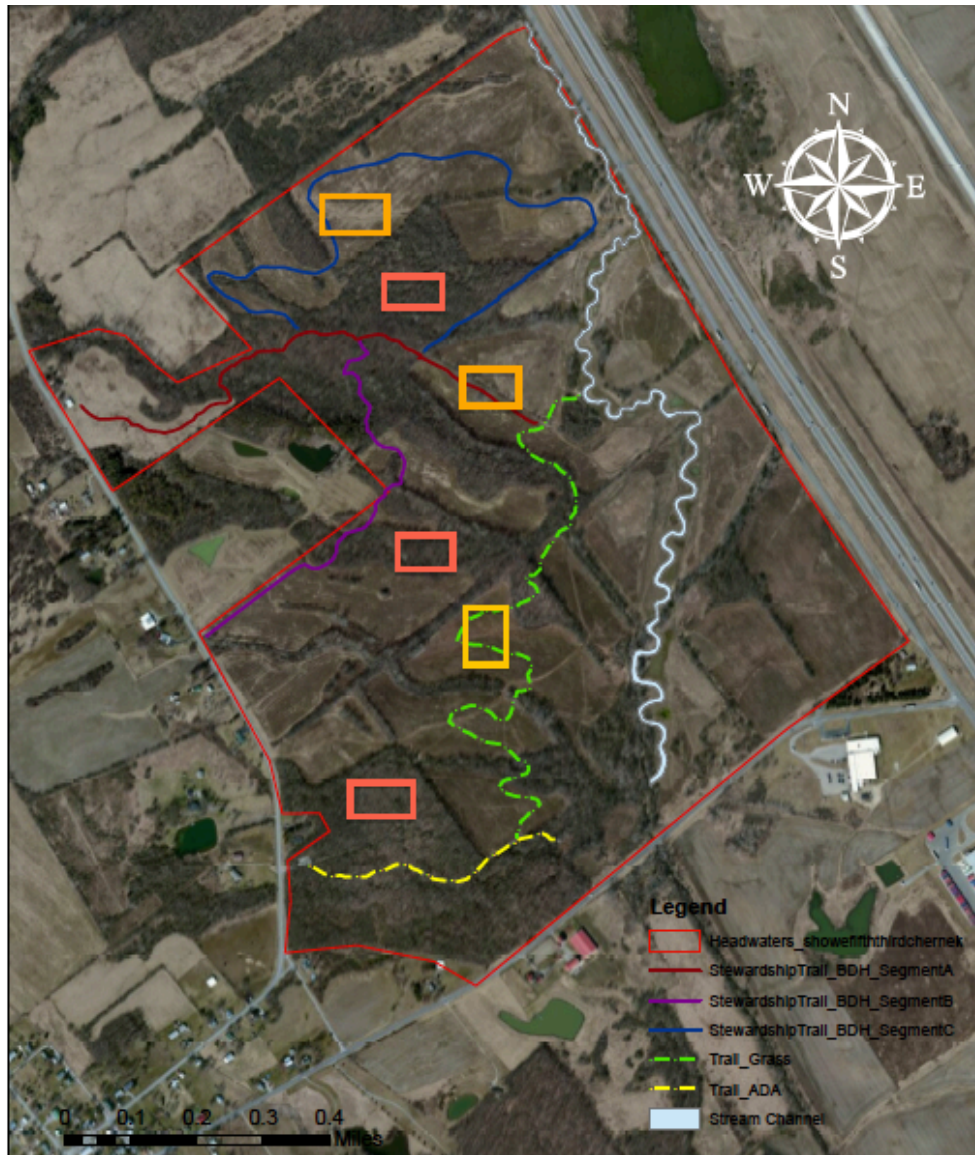


Figure 11. Aerial photo showing the location of the soil transects in both wooded and open field areas in the study area.

## Soil Data Results

All data entries were entered through the statistical program SAS (Statistical Analysis System). This statistical program was used because it was the most readily available program to run. Five parameters were input through SAS: N-P-K, soil moisture, electrical conductivity, temperature (in degrees Celsius), and pH. Alpha was always within a 5% (alpha at 0.05). The post hoc test utilized was Duncan's new multiple range test (MRT). This was used to determine whether the means differ significantly in an analysis of variance. Duncan's MRT is protective against false negative (Type II) error at the expense of having a greater risk of making false positive (Type I) errors.

**Table #2. The mean values<sup>1</sup> of different soil parameters**

<b>Land use</b>	<b>n</b>	<b>N-P-K</b>	<b>Electrical conductivity mS/cm</b>	<b>Soil temperature (oC)</b>	<b>Soil pH</b>	<b>Soil moisture (percent)</b>
Wooded	9	4.93 A	0.1026 A	17.90 A	6.47 A	10.10 A
Field	9	4.56 A	0.3674 B	19.61 B	6.63 A	16.62 B

<sup>1</sup> Mean values followed by the same capital letter are not significantly different at  $p=0.05$ , Duncan's new multiple range test.

Looking at Table 6. the ratio of nitrogen, phosphorus and potassium were not found to be statistically significant using the Duncan Grouping, between transects taken from wooded areas vs. open field areas. However, the soil electrical conductivity, soil temperature, soil moisture, and pH were found to be statistically significant using the Duncan Grouping, between transects taken from wooded areas vs. open field areas. The mean in A is more significant since it is a larger number. The importance of A and B is that the means are significantly different from each other.

**Discussion:**

Looking at all five parameters, only three were found to be statistically significant. NPK was shown to be not significant, this result means that the soil fertility according to the NPK readings is the same across all soil transects regardless of vegetation. Electrical conductivity was found to be statistically significant. This means that there is more dissolved cations and anions in the solution, more dissolved salts equal a greater electrical conductivity. If the electrical conductivity becomes too high in the soil, plant mortality may occur because of the soluble salts, which the plants readily take up. This may stunt, disease or kill planted hardwood species.

Soil temperature was found to be statistically significant. This means that there was a temperature difference between the wooded and open field. This could be due to the fact that the open field has a greater albedo, and reflecting more of the light back, whereas the soil in the wooded area has canopy cover, and is less likely to be warmed by direct sunlight. From the perspective of a hardwood tree propagule, the data states that conditions are wetter, warmer and higher EC under open fields than under forest canopy. Soil pH was not found to be statistically significant. Soil moisture was found to be significant. Therefore, there is more soil moisture available in the open field as opposed to the available soil moisture in wooded areas.

**Conclusion:**

The combination of statistically significant higher levels of moisture, temperature and dissolved salts under agricultural old field cover versus forest cover may present site conditions that are less suitable for the regeneration, via natural seed dispersal, of forest in these old fields and may explain, in part, the observed slow recovery of hardwood forest in the old field areas

studied and those nearby.

The five parameters used in this study could be enhanced with more transects, better tools, and organic carbon testing.

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